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Characterization of Oil Palm Frond Juice and Fiber as Feedstock for Biobutanol Production

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Abstract

The interest in biobutanol fuel is driven by the need to expand the search for alternative fuels from sustainable source specially those that use abundant and low cost feedstock. Oil palm frond offer a promising sugar feed stock for fermentation as it is available throughout the year and regularly pruned during harvesting of fresh fruit bunches in oil palm plantation. The aim of this research is to study the characteristics of oil palm frond (OPF) juice extract and fiber as a feedstock for biobutanol production. In this studyliquid extracts are pressed from the respective OPF petioles and total reducing sugar content was analysed using DNS method and the result shows that the glucose concentration was 40.50g/L. Furthermore,content of sugar is highly affected by the age of oil palm tree which affected the content of sugar in the liquid extract of OPF.The high cellulose and low lignin content of 41.53% and 6.27% obtained from lignocellulose content analysis conducted using acid detergent filter (ADF), neutral detergent filter (NDF) and acid detergent lignin (ADL) methods as described by (Omar et al., 2011),indicates the suitability of Oil Palm Frond (OPF) as a promising feedstock for biobutanol production. Hence, conversion of oil palm plantation residues to green fuel can enhanced energy security and offers the potential for sustainable transport fuel in the future.

Keyword*: oil palm frond, juice extract, biobutanol, plantation, feedstock,*
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1. Introduction

Malaysia is blessed with an abundance of biomass and biofuel capture potentials from its oil palm industry and plantations(Foo-Yuen et al., 2011).Therefore, the availability of fronds during the pruning activity was evaluated using an approximation of 10.4 tonnes ha^{-1}, which currently gives an average of 6.97 million tonnes per year. Meanwhile, it was estimated that an average of 54.43 million tonnes per year of oil palm fronds will be available during the replanting process between 2007 – 2020 (Ratnasingam and Jegatheswaran, 2011). However, most of the OPF are left decaying between the rows of palm trees, mainly for soil conservation, erosion control and ultimately for the long-term benefit of nutrient recycling .The efficient utilization of this agricultural waste as raw material for the production of biofuels can therefore serve as an alternative to food crops feedstock.

Many findings on bioconversion of oil palm agricultural waste as fermentable sugar for eventual production of biofuel have been reported (Zahari et al., 2012, Nguyen et al., 2010, Yamada et al., 2010, Koutinas et al., 2007, Tengerdy and Szakacs, 2003, Wan Zahari et al., 2002) . Oil palm frond (OPF) obtained during harvesting and pruning is one of the main by-products of the oil palm industry in Malaysia and has been the main contributors to the generation of agricultural waste, accounting for about 83 million tonnes of wet weight in 2009 (MPOB, 2011) .In 2012, it is estimated that about 83 million drytonnes of solid biomass is produced annually on a dry matter basis (Figure2.). This volume is projected to increase to 85-100 million dry tonnes by 2020 (A.I.M., 2013) . Most of these solid biomass found in plantation are fronds and trunk accounting for about 75 percent of solid biomass volume, the remaining 25 percent is generated in the mills during the extraction of oil palm.

Oil palm frond juice and pressed fibers have the potential to be converted to fermentable sugar for the production of value added products such as bioethanol, biobutanol and bioplastic (Zahari*et al*., 2012). In addition, lignocellulose materials of oil palm frond fiber can be converted into biobutanol, bioethanol and other value added products by means of biological and chemical processes (BasironYosuf*et al.*,2010). Research on sugar production from oil palm frond by Kosugi et al 2010 revealed that high amount of readily available sugar were contain in the oil palm frond (OPF). Furthermore, the production of sugars from dried oil palm frond has recently been reported (Fazilah et al., 2009, Goh et al., 2010) . Recent studies have indicated that renewable sugar can be obtained from oil palm frond by the application of simple extraction technology using conventional sugar cane pressing machine (Che Maail et al., 2014) .

Currently oil palm frond is mostly used for the purpose of compost and left to decay in plantation as fertilizer. These practices creates environmental problem, hence alternative ways to utilize this abundant resources are needed (Tan et al., 2011) . The viability of OPF feedstock for biobutanol production depends on cost effectiveness, local availability, better yield of products, feedstock handling with minimum risk of health and safety (Ray, 2013, Che Maail et al., 2014). However, the main problem with oil palm frond extraction is the handling and processing period, which results in degradation of sugars. Hence the objectives of the present study is to characterize the renewable sugar content in OPF juice extract and fiber for biobutanol production.

2.0 Material and Methods

2.1. Raw Materials

Samples of oil palm petiole collected from oil palm trees of different ages weighing 10kg (5-9 years) 12kg (10-15years) and 13kg (15-25 years) for a total of 35kg were obtained from local oil palm plantation in Batu Pahat. All the petiole were kept in sealed plastic bags at ambient temperature (27-30^{0}C) prior to pressing.

2.2. Juice Extraction Process

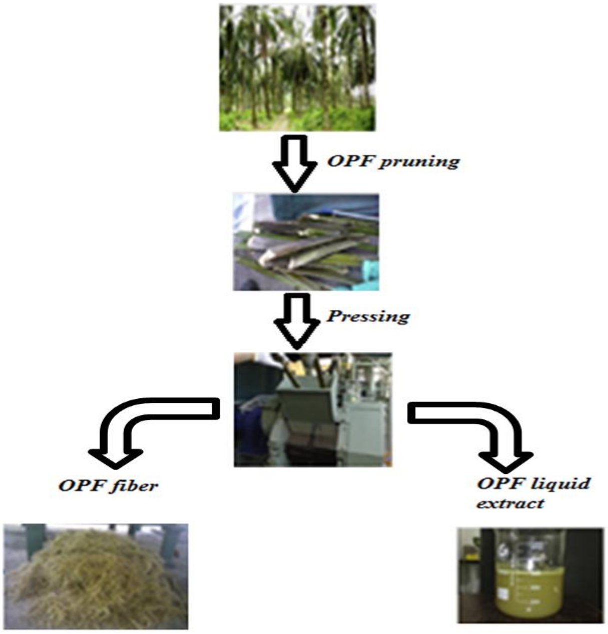
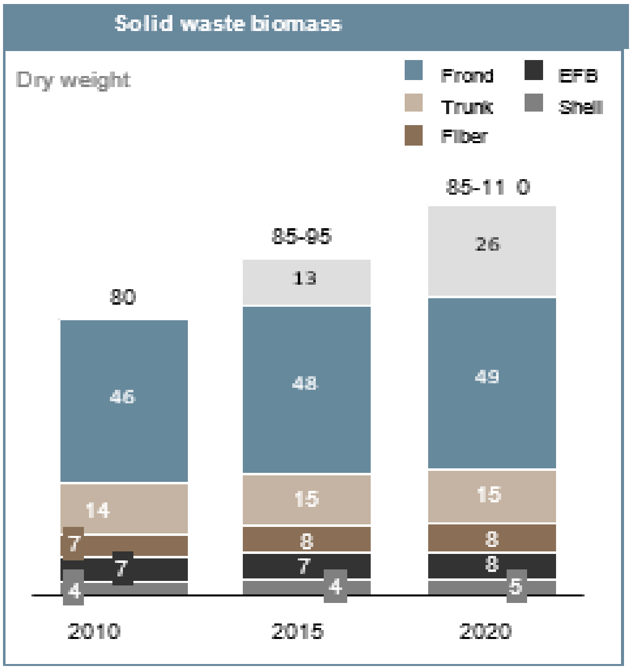


Figure1. Flow Diagram of Oil Palm Frond Extraction Process

Extraction was conducted at Automotive Development Centre (ADC), Universiti Teknologi Malaysia (UTM) using sugar cane pressing machine (Elephant W.H.L) model. The steps were repeated several times to obtain desired quantity of juice. The juice extract were then filtered to remove fibrous debris. The filtrate extract was then stored at 4^{o}C prior to sugar analysis as indicated in Figure1. Juice extraction process is challenging owing to difficulty in maintaining aseptic condition attributable to environmental condition during pressing. To obtain juice extract from oil palm frond that is perishable, nutritionally rich hence suitable for bacterial growth, sterility measures ought to be maintained during pressing and storage.



Source:(A.I.M., 2013)

Figure 2. Estimated availability of solid waste (Million tonnes on dry weight basssis in Malaysia by year 2020.

Table1. OPF Samples and the Amount of OPF juices Extracted at Particular Time

Oil palm tree age (years)	Weight of OPF petiole (kg)	Extraction period* (hours)	Quantity of OPF extract (L)
20-25	8	6	1
15-20	10	24	1.2
10-15	12	48	1.4

*the time between collection of OPF and the time of OPF juice extraction

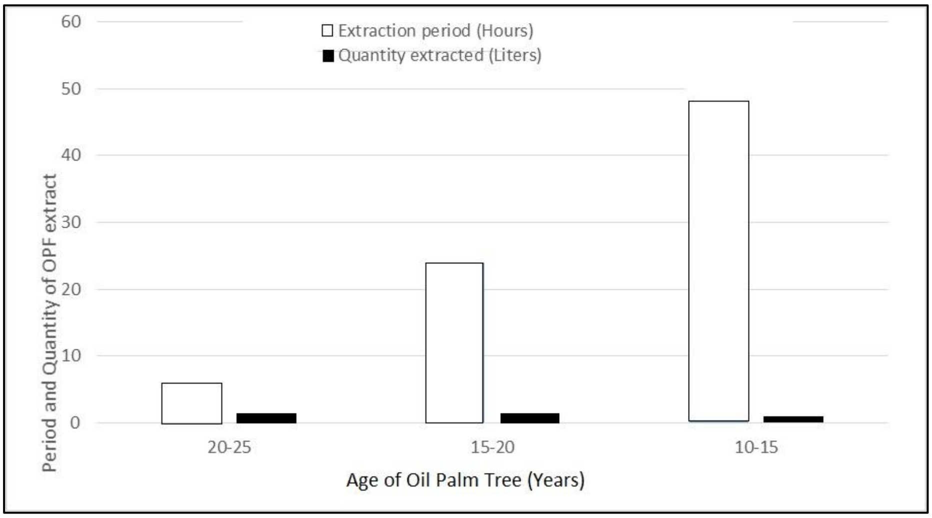


Figure 3. Oil palm frond Extraction Characteristics

Table 2. Spectrometer reading of sample solution.

Oil palm tree age (years	Spectrophotometer Reading	Glucose concentration (g/L)
20-25	0.839	40.50g/L
10-15	0.748	36.11g/L
15-25	0.357	17.23g/L

2.3. Determination of reducing sugar concentration.

Dinitrosalicyclic acid (DNS) method is used to determine the reducing sugar concentration as representative of the total monosaccharide or disaccharide present based on usual standards. The concentration of glucose was calculated from the linear regression equation obtained from a standard calibration of glucose (*r =0.9843)* with linear regression y *=1.0357x* (where y is the absorbance value of sample from DNS assay and *x* is concentration of glucose).Therefore, glucose concentration for the three samples were determined as 40.50g/L, 36.11g/L, and 17.23g/L respectively as shown in (Table 2).

Table 3. Fibre analysis of pressed OPF fibre

Components	Amount (%)
Cellulose	41.53
Hemicellulose	20.89
Lignin	6.27
Ash	5.80

2.4. Lignocellulose content analysis of OPF fiber

Lignocellulose content of chemically untreated OPF were analysed using acid detergent filter (ADF), neutral detergent filter (NDF) and acid detergent lignin (ADL) methods as described by (Omar et al., 2011). The content of lignin, cellulose, hemicellulose and ash of the OPF fiber were computed using the equation below and results are presented in Table 3.

Cellulose (%) = ADF-ADL
Hemicellulose (%) = NDF-ADF
Lignin(%) =ADL

Table 4. Proximate analysis of oil palm biomass (%, dry weight)

Component	Oil palm trunk	Oil palm fronds	Empty fruit bunch
Lignin	18.1	18.3	21.2
hemicellulose	25.3	33.9	24.0
α- cellulose	45.9	46.6	41.0
holocellulose	76.3	80.5	65.5
Ash	1.1	2.5	3.5
Alcohol-benzene solubility	1.8	5.0	4.1

Adopted from (hhttp://www.bfdic.com, 2010)

3. Results and Discussion

The result of glucose concentration in OPF Petiole presented in Table 2, shows that the highest sugar concentration of 40.50g/l was recorded from the OPF collected from palm oil tree of 15-25 years, compare to 36.11 g/L and 17.23 g/L obtained from 10-15 and 5-10 years old tree, respectively. This indicated that the sugar content is highly affected by the age of oil palm tree. The age of oil palm tree shows adverse effect on the content of sugar in the liquid extract of OPF, as the lowest amount of sugar obtained in the OPF sample was from the youngest oil palm tree as shown in Figure 2. This observation is similar to that reported by Che (Che Maail et al., 2014) .

The cellulose, hemi-cellulose, and lignin contents of the fresh OPF in this study were 41.5%, 20.9% and 6.3%, respectively. Notably, the cellulose and hemi-cellulose contents in the fresh pressed OPF were comparable to those obtained by other researchers, (Dahlan, 2000); (Wan Zahari et al., 2002) ; (Zahari et al., 2012)). The lignin content of oil palm fiber in this study is relatively low compared to other oil palm biomass such as oil palm trunk (OPT) and oil palm empty fruit bunch (OPEFB) which have lignin content ranging from18-21% as indicated in Table 4. Thus, low lignin content is an advantage. .It is interesting to note that the present study indicates that the freshly extracted OPF exhibits a high cellulose content.Furthermore, in the OPF fibre, the high carbon content is contributed to the high content of cellulose and hemicellulose, as indicated in Table 3.

As cellulose and hemicellulose are complex biomolecules, further hydrolysis is required to produce fermentable sugars prior to the production of biofuel. The potential amount of renewable sugars from OPF can be increased if saccharification is done to further enhance the sugars yield from the fiber.Based on the characterization results, OPF juice and fibre meets all the criteria as better fermentation substrates as they are renewable and consistently available.

4. Conclusion

The present work shows that OPF juice extract and fibre have promising characteristics as a renewable feedstock for biobutanol production. A substantial amount of sugar 40.50g/l obtained in addition to the percentage cellulose and lignin content of 41.5% and 6.3% for OPF fibre is an indication of viability of OPF as a promising new fermentation feedstock for biobutanol production. Low lignin content of OPF is an added advantage. Furthermore, OPF extract is rich in nutrient which are essential for bacterial growth and eventual production of the biobutanol fuel. Therefore, conversion of oil palm plantation residues to green fuel can safe guard the environment.

REFERENCES

A.I.M. (2013) *New wealth creation for Malaysia's biomass industry*: National Biomass Strategy.

Che Maail, C. M. H., Ariffin, H., Hassan, M. A., Md Shah, U. K. and Shirai, Y. (2014) 'Oil Palm Frond Juice as Future Fermentation Substrate: A Feasibility Study, *Biomed Research International*, 2014, pp. 1-8

Dahlan, I. (2000) 'Oil palm frond, a feed for herbivores. ', *Asian-Austrian. Journalof Animal Science*, 13, pp. 300-303.

Fazilah, A., Azemi, M. N. M., Karim, A. A. and Norakma, M. N. (2009) ' Physicochemical properties of hydrothermally treated hemicellulose from oil palm frond', *J. Agric. Food Chem.,* 57, pp. 1527-1531.

Foo-Yuen, N., Foong-Kheong, Y., Yusof, B. and Kalyana, S. (2011) 'A Renewable Future Driven with Malaysian Palm Oil-based Green Technology.', *Journal ofOil Palm &Environment,* 2, pp. 1-7.

Goh, C. S., Tan, K. T., Lee, K. T. and Bhatia, S. (2010) 'Bio-ethanol from lignocelluloses: status, perspective and challenges in Malaysia.', *Bioresource Technology,* 101, pp. 4834-4841.

http://www.bfdic.com (2010) 'Beijing Forestry and Parks Departement of International Cooperation', pp. 07-16

Koutinas, A. A., Xu, Y., Wang, R. and Webb, C. (2007) 'Polyhydroxybutyrate production from a novel feedstock derived from a wheat-based biorefinery. ', *Enzyme Microbiolgy Techechnology,* 40, pp. 1035-1044.

MPOB, M. P. O. B.-. (2011) *Overview of the Malaysian oil palm industry 2010*: Ministry of Plantation Industries and Commodities Malaysia

Nguyen, T. A. D., Kim, K. R., Han, S. J., Cho, H. Y., Kim, J. W., Park, S. M. and Sim, S. J. (2010) ' Pretreatment of rice straw with ammonia and ionic liquid for lignocelluloses conversion to fermentable sugars.', *Bioresource Technology,* 101, pp. 7432–7438.

Omar, R., Idris, A., Yunus, R., Khalid, K. and Aida Isma, M. I. (2011) 'Characterization of empty fruit bunch for microwave-assisted pyrolysis. ', *Fuel,* 90, pp. 1536-1544.

Ratnasingam, A. and Jegatheswaran, T. (2011) 'Oil palm biomass utilization-Counting the success in Malaysia', *Available from http://www.woodmagazine.com/node/417*.

Ray, A. (2013) 'Second-generation hydrocarbon fuels from oil palm by-products', *Journal of oil palm & Environment,* 4, pp. 22-28.

Tan, H. T., Lee, K. T. and Rahman, M. (2011) 'Pretreatment of lignocellulosic palm biomass using a solvent-ionic liquid[BMIM]CI for glucose recovery : An optimization study using response surface methodology.', *Carbohydrate Polymers,* 83, pp. 1862-1868.

Tengerdy, R. P. and Szakacs, G. (2003) ' Bioconversion of lignocellulose in solid substrate fermentation.', *Biochem. Eng. Journal,* 13, pp. 169-179.

Wan Zahari, M., Abu Hassan, O., Wong, H. K. and Liang, J. B. 'Utilization of oil palm frond - based diets for beef and dairy production in Malaysia.'. *Recent Advances in Animal Nutrition'* ,New Delhi, India, , September 22, 2002

Yamada, H., Tanaka, R., Sulaiman, O., Hashim, R., Hamid, Z. A. A., Yahya, M. K. A., Kosugi, A., Arai, T., Murata, Y., Nirasawa, S., Yamamoto, K., Ohara, S., Yusof, M. N. M., Ibrahim, W. A. and Mori, Y. (2010) ' Old oil palm trunk: a promising source of sugars for bioethanol production.', *Biomass Bioenerg.*, 34, pp. 1608-1613.

Zahari, M. A. K. R., Zakaria, M. R. and Ariffinetal, H. (2012) 'Renewable sugars from oil palm frond juice as an alternative novel fermentation feedstock for value-added products', *Bioresource Technology*, 110, pp. 566-571.